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Modern techniques used to improve a hearing conservation program in a power generating plant

Eilyn Fabregas

ABSTRACT

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A noise survey was conducted on the pump floor of a power generating plant, which included measuring noise levels at 261 areas of the floor (6,000 square feet) and the employees' noise doses, or 8-hour time-weighted average (TWAs). The noise levels of the 261 areas were recorded using a Sound Level Meter, and the noise doses (i.e., TWAs) were measured using a noise Dosimeter. It was found that both noise levels and TWAs were higher than the OSHA's permissible exposure limit (PEL) of 90 dBA and the action level of 85 dBA. According to the data gathered, it was determined that at least single hearing protection devices are mandatory while working on the pump floor after evaluating noise attenuation using both single and double hearing protection. Finally, baffles, enclosing walls, preventive maintenance, and behavior modification techniques and incentive programs are recommended in order to attenuate noise exposure levels to safety levels and improve hearing protection devices usage among employees.

MODERN TECHNIQUES USED TO IMPROVE A HEARING CONSERVATION PROGRAM IN A POWER GENERATING PLANT

by

Eilyn Fabregas

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APPROVAL PAGE

Modern Techniques Used to Improve a Hearing Conservation Program in a Power Generating Plant

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To

my husband Jose R.

and my parents Gloria and Frankie

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CHAPTER 1

INTRODUCTION

1.1 History

Since the OSHA 1910.95 Noise Standard was promulgated in 1974, it has been found that the number of facilities and employees that are not complying with the regulation is noticeably high. For example, an industrial noise survey of 283 utility companies revealed that 40% of those interviewed said that less than 25% of their employees use Hearing Protection Devices (HPDs) as required (National Safety Council, 1983) and 14% of the working population is employed in jobs where the noise level is in excess of 90 dBA. Without considering those who are exposed to industrial noise, the American Industrial Hygiene Association (AIHA) conducted a study which reveals that 20% of the general population between age 50 and 59 will experience hearing losses without any exposure to industrial noise (Plog, 1988). Some of the reasons employees give for not using HPDs are: their unpleasant adaptation period, concern for cleanliness when using earplugs, lack of fitting into the ear canal and increased sweating around the ear when wearing earmuffs. For this reason, several efforts to increase user acceptance of personal ear protectors have taken a variety of forms such as design and material changes in the devices to improve their comfort.

When engineering and administrative controls are not feasible, hearing protection devices should be used to reduce the level of noise entering into the ear canal. Many X theory-oriented companies have relied on punishment to increase HPD usage among employees. However, punishment strategy's unwanted results may lead to active resistance of the employees because they believe it poses a threat to their personal freedom. It gains only compliance from workers not acceptance. On the other hand, management has over-relied on punitive methods creating company cultures characterized by negative attitudes about safety improvement. Supervisors and managers resist "writing up" their employees because they make themselves more liable to receive negative consequences from top level management when accident rates get worse. For this reason, supervisors and managers tend to reclassify injuries to make the numbers look better. It is very important to mention that even when employees know that repeated exposure to high levels of continuous noise can cause permanent hearing loss, such knowledge often lacks of any motivating qualities or personal relevance.

The primary purpose of this study is to determine what the noise levels of worksites are. It has been recognized that one potential source of hearing impairment among power generating plant's employees is the exposure to high noise levels. The secondary purpose of the study is to suggest a behavior modification method in order to change employees' unsafe behavior to safe ones. The first step is to define what the present workers' behaviors are and then suggest what the desired behaviors would be in response to some kind of intervention strategies. In this case, the undesired unsafe behaviors are employees' reluctance to wear hearing protection, and the expected result will be employee commitment to use HPDs by complying Behavior Modification Techniques. Past safety personnel and top level management never encouraged employees to use HPDs.

There are three major factors contributing to accident causation: physical environment, personality and individual's attitudes including traits and knowledge, and finally, behavior (Geller, 1989).

CHAPTER 2

LITERATURE REVIEW

2.1 Sound

There are four principal factors, called the noise exposure factors, that affect the degree of hearing loss: the intensity of the noise (sound pressure level); the type of noise (frequency spectrum); the period of exposure each day (duty cycle per day); and the total work duration or years of employment (Plog, 1988).

Noise induced hearing loss (NIHL) describes the cumulative permanent loss of hearing. This could be achieved by measuring the sound levels as well as determining the TWAs. Feasible administrative controls, engineering controls, or personal protective equipment (as a last resource) shall be utilized when employees are subjected to noise levels of 90 decibels (dB) time-weighted average (TWA) or higher (OSHA, 1992).

Another way to determine whether a person is overexposed or not is by calculating his/her noise dose. If it exceeds unity or 100%, then the exposure should be considered as exceeding the limit value. However, as soon as an 8-hr TWA of 85 decibels or a dose of 50% are reached, an action level has also been reached. Even when the TWA does not exceed the action level, it is essential that acoustic warning signals be detectable above the background sound level (Berger, 1986). Another reason, according to Berger, to conduct a sound survey is to investigate potential safety hazards related to employee communication and detection of warning signals.

2.2 Behavior Modification Techniques

One of the purposes of applying Behavior Modification Techniques using rewards (i.e., incentives program) is to anticipate, prevent or at least minimize unsafe behaviors before they occur. It is well-known that more than 80% of all injury accidents are caused by human behavior or in other words, by unsafe practices. The so-called "iceberg" concept states that for every accident there are thousands of unsafe acts and practices. Because these unsafe acts are the root of the problem, they should be eliminated. It is also useful to change the culture of the organization by observing and correcting the behavior of management, supervision and workforce so that, over time, attitudes toward safety will result in a much safer business. It is very important to mention that a safety program should be accepted as a personal responsibility by each member of management, supervision, and the workforce in order to have an effective impact on the overall performance.

A system of rewards is used to maintain consistent and continued safety performance by recognizing individuals' safety efforts. Several studies have been conducted to promote the use of Personal Protective Equipment (PPE) by using Behavioral Modification Techniques. According to Zohar (1980), a 35% earplug usage increases to an average level of 85-90% as achieved by using two behavior modification techniques, individual feedback to workers regarding their temporary hearing loss and two versions of a token economy system. The new level remained stable despite large turnover rates. This means that new employees are molded by the culture (peer pressure, role modeling, co-workers sanctions) to conform to its expectations. It is very important to mention that top level management as well as involved workers were participating in this behavior modification programs.

A similar study where workers in a noisy department of a metal fabrication plant took hearing tests before and at the end of their workshifts, while wearing hearing protection or not (i.e., earplugs), resulted in a steady increase attaining a level of 85-90% (Zohar, Cohen & Azar, 1980). After the hearing tests were taken, these were explained to the employees and the audiograms were posted. On both studies, experimental and control groups were studied using behavior sampling techniques. Group lectures and poster campaigns were used before the behavior modification program was implemented to try to increase employees usage of hearing protection but with no success.

Water consumers in a residential area in Virginia received handbooks, written informational feedback with social commendation and installed sets of water conservation devices as part of a study promoting residential water conservation by using educational, behavioral and engineering strategies (Geller, Erickson and Buttram, 1983). In other industries, sophisticated engineering designs are introduced to minimize the chance of major accidents. In this case, the mean daily water consumption across all the residences decreased by ten gallons (from the Baseline phase to the Treatment phase) and 17 gallons per day when devices were installed. For those residences where devices were not installed, an average of only a four gallon daily reduction was achieved. Prior studies which used only educational approaches were found to have minimal influence. In this study particularly, the resource cost dramatically influenced the results of the study. According to Geller et al (1983), there is a direct relation between the resource cost (i.e., water prices) and the feedback strategies impact. Winkler (1982) reported that where water prices are low, behavioral intervention can be expected to have minimal or no influence.

There are three primary considerations to keep in mind when designing a safety incentive award program: the training involved to maintain safety, the duration of the award period and employee preferences (Eisma, 1991). Its' primary objectives are, to follow safe procedures and to prevent accidents and hazardous exposure. The more important features of a successful program are its generosity towards the workers, its short-term and continuous duration and its positive approach. In order to increase the effectiveness of the program, a safety training program should already be in place. The length of the award program should be relatively short. Incentive awards may include: gifts of quality, personalized or safety slogan items, brand-name watches, recognized-name gift certificates, cash, lottery tickets,etc. Managers should consider safety records in promoting workers. Unfortunately, lottery award programs are not as effective as those based on awarding the whole workforce. It allows only one person at a time to be recognized. On the other hand, cash awards are generally ineffective in that the money is pocketed, spent and forgotten. In choosing an appropriate award, the program administrator should look at the attitudes and preferences of the workers.

In the study conducted by Kello, Geller, Rice and Bryant (1988), signing pledge cards (regardless of the pledge duration) did not produce significantly greater increases in safety belt use than the awareness sessions without the pledge cards. On the contrary, when compared to other studies, some of the findings revealed that once rewards were withdrawn, safety belt often declined rapidly approaching baseline levels after no more than three to four weeks (Geller, 1983; Geller et al., 1983; Geller & Hahn, 1984).

According to Krause, Hidley and Hodson (1990), "the behavior-based approach improves company culture by identifying and then managing a change in behaviors which are critical to safety". Attitudes, values and on-site work habits which are shared among employees are factors that characterize and exert a powerful influence on the company's safety culture. It has been identified that measuring workers' attitudes is not feasible, whereas behavior can be identified and measured. There are five elements involved in understanding such behavior: the person, the behavior of the person, the stimuli, the effect of the behavior, and the inner drives (Odiorne, 1991). Motivations, perceptions, personality traits, attitudes, tension or social influences are some of the inner drives that act upon a person to produce a certain behavior. Behaviors are influenced by the stimuli proceeded them (stimuli-response theory). Another stimulus-response theory says if a behavior is followed by a satisfier, the behavior that produced that effect will occur again.

An example of the behavior-to-attitude change is the use of seat belts in automobiles. In the early days, drivers' favorite "excuse" for not using safety belts was that they felt uncomfortable wearing them. Kello et al (1988) used extrinsic rewards and pledge cards (intrinsic rewards) to induce people buckle up demonstrating that the problem still exists and it can be resolved by using motivational techniques. The results were a three-fold increase in safety belt use. On the contrary, neither pledging cards nor duration had any differential effect on likelihood of signing or subsequent compliance.

One of the goals of a behavior modification program is to promote employee involvement by increasing their responsibility for the performance of the company. Part of these responsibilities is to define the facility's inventory of critical behaviors by identifying the actions needed to perform a job safely, and the unsafe acts that could lead to injuries or accidents. In other words, spot likely injuries before they occur (proactive approach). It is well known that 80% to 95% of accidents are attributable to unsafe behaviors. After developing the list of critical behaviors, the next steps are: training the observers, measuring baseline safety performance, and finally, feedback and training. Collinge (1992) says that an auditing process should include the following: observations of people's activities, discussions with the workers how the job can be done more safely, recording the unsafe acts and conditions, and finally, follow-up. When an accident happens, all other employees should be shown what caused the accident and what can be done to prevent it.

Accident frequency rates have been identified as a limited indicator of real performance and do not provide additional information about other factors such as exposure, management systems or culture. For instance, when a facility's accident frequency rate is low (few or no injuries), one tends to think there are no unsafe behaviors, and safety performance is good or at least improving. Conversely, when the frequency rate increases (accidents have occurred), one tends to conclude that safety performance is declining, and unsafe behaviors have increased. None of the above mentioned examples need to be true. It has been stated that the injury frequency rate is of no predictive value to safety management on any time basis.

Another tool used by some companies to improve their safety performance is the Job Candidate Profile (JCP) (Krause, 1992). It is a pre-selection criterion in the job applications process that helps managers select safe, dependable and productive employees by measuring applicant characteristics. The applicant's score is compared to a computerized database of normative scores. JCP data shows that people who have low scores tend to 5 times as many on-the-job injuries.

Another useful tool frequently used to pin point and avoid future accidents are Standard Operating Procedures

(SOP's) where the appropriate steps necessary to perform a job safely are listed and explained. Companies can select those employees who perform their job safely, get their input of how they perform their job, develop a standard method of how to perform it and then train their employees by using SOP's.

Table 1 Number and Types of Injuries During 1992

Types of Injuries	1991	1992
Abdomen	0	0
Ankle	2	2
Arm	1	1
Back	4	2
Ear	0	3
Eye	8	3
Finger	5	2
Hand	2	0
Knee	3	0
Leg	2	2
Neck	0	0
Shoulder	1	1
Skin	0	0
Elbow	1	0
Hip	0	0
Head	0	0
Feet	1	0
Others	1	1

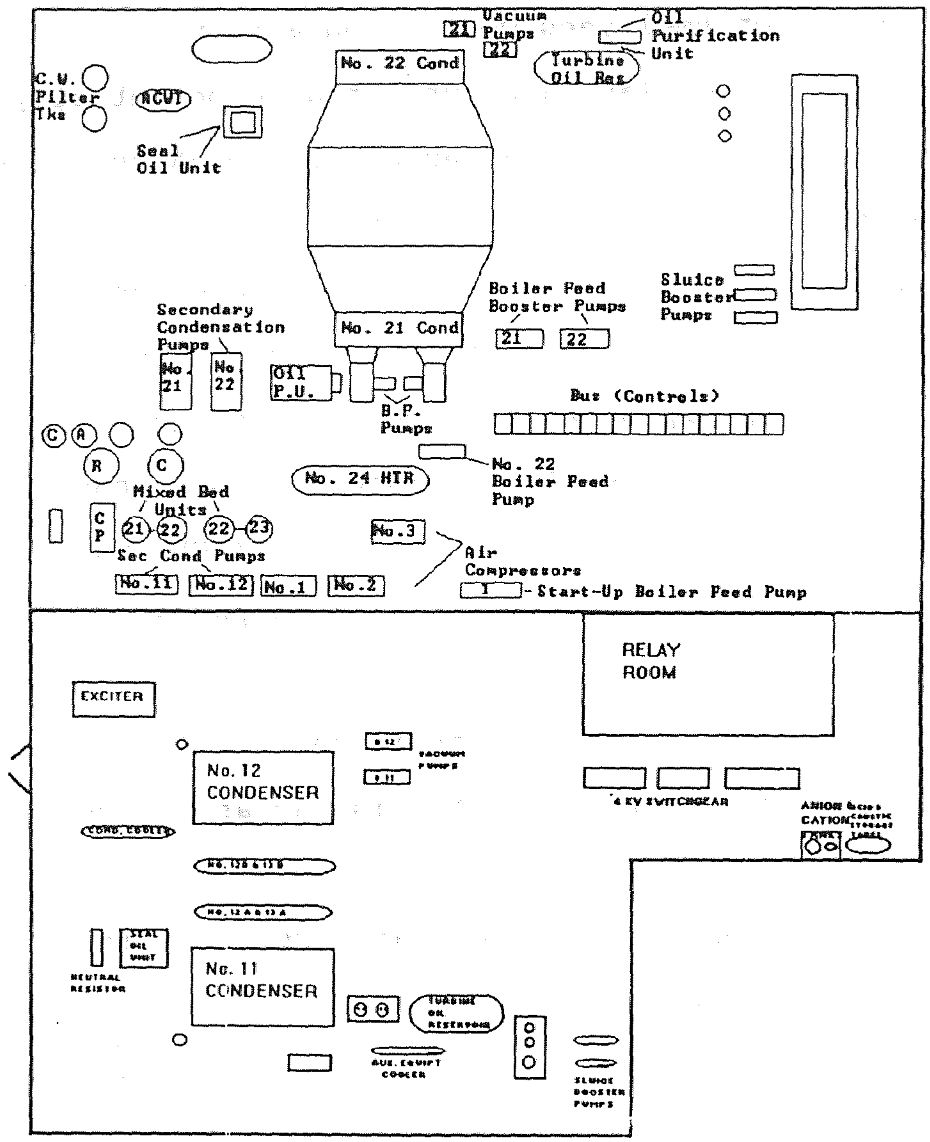
CHAPTER 3

OBJECTIVE

The primary objective of this study is to determine whether or not employees working on a pump floor of a power generating plant are subjected to potentially hazardous noise levels that exceed the OSHA 90 dBA PEL (permissible exposure limit) or the 85 dBA action level, calculated as an 8-hour, time-weighted average (TWA). Then, as a secondary goal of this study, a feasible method to help employees to commit to wear HPDs is recommended. As a result, the sound survey phase of the company's hearing conservation program (HCP) has been developed and executed in the ensuing pages.

There are two reasons which help determine if a noise survey on the pump floor is necessary. First, the pump floor is one of the most noisy areas in the whole generating station. It is very annoying when walking through the pump floor without any type of hearing protection device. The second and the more important, is that hearing loss is one of the leading causes of injuries in the station (See Table 1). Those people with hearing damage have suffered Standard Threshold Shifts of 10 dBA or more.

Figure 1 Pump Floor Layout (Units #1 & #2)



CHAPTER 4

METHOD

4.1 Machinery

The pump floor, with physical dimensions of approximately 6,000 square feet, is mainly composed of two boilers, which are called number 1 and number 2 units, and their respective machinery, including air compressors, feed pumps, sluice pumps, regeneration pumps, storage tanks, booster pumps, condensers, heaters, and so on. This type of machinery is considered steady-state noise generators. Number 1 unit works with either oil or gas and number 2 unit works with coal. Because number 2 unit is more efficient, it is more frequently used. The area has been identified by floor grid which is divided into 261 sections. Each section represents an actual size of 20 square feet. The floor drawing's "X" axis is identified with letters from A through L (for number 2 unit) and from A through H (for number 1 unit). The "Y" axis is identified with numbers from 1 to 16, for both units respectively. A pump floor layout is shown in Figure 1. Furthermore, there was no sound insulation or noise reduction treatment (such as viscoelastic material added to the surface of thin steel partitions) installed on the floor, ceiling or walls at the time of the study. Because the floor, ceiling and walls are made of concrete they provide an effective barrier to dissipate noise confining it within the walls, which is a big problem.

4.2 Equipment and Calibration

4.2.1 Equipment

The instruments used for this study included a sound level meter (SLM) and a noise dosimeter. The SLM was used to determine the noise exposure level for a given time period. The sound level meter used in this survey was the Quest model 2400 Sound Level Meter which delivers Type 2 accuracy for noise measurements and statistical analysis, and meets the ANSI S1.4-1971 (R1976) Standard Specifications for Sound Level Meters, Type 1 or 2.

4.2.2 Calibration

Before taking any measurements, both the sound level meter and dosimeter were calibrated. The SLM calibration basically consists of: a battery check, turn the CA-12B calibrator ON, place the black adapter ring fully onto the microphone, place the CA-12B onto the adapter and set the SLM to RUN, SLOW or FAST, HIGH range. If necessary to adjust the SLM, a small screwdriver is used to adjust the potentiometer until the display reads 110.0 dB ± 0.1 standard deviation. The calibration was also checked after each use.

The dosimeter calibration consists of two types: the daily calibration and the yearly calibration. For the purposes of this study, the daily calibration was performed. Before each use, the dosimeter calibration was done. It consists of the following steps: after removing the windscreen, inserting the microphone in the microphone adaptor and placing the adaptor in the calibrator, turning on the CA-12B calibrator, pressing CODE/HL3 until CAL is displayed, and pressing SOUND LEVEL. If the level is between 109.0 dBA and 111.0 dBA, press PAUSE/RESET until CAL is displayed. A small screwdriver is used for adjusting, if necessary. The instrument's calibration level is recorded and displayed later on the dosimeter printout.

4.3 Collection of Noise Exposure Data

The primary purpose of acquiring data with the SLM is to determine the actual noise level an employee could be exposed to while working at different locations in the pump floor, and also to determine the dominant noise sources. With this information in hand, noise exposure hazards can be readily identified using measured sound level contours. The SLM was tripod-mounted at a height of approximately 1.5 meters above the floor. Even when the pump floor is a "closed room", a windscreen was used all the time in order to prevent erroneous measurements when working around the machinery fans.

facing 17

Figure 2 Noise Survey Data Form

GRID	LOCATION	DB1	DB2	DB3	DB4	DB5	DB6	DB7	DB8	DB9	DB10	MEAN

A reading was taken from every area of the pump floor, one every day. For readings, popular A-weighing was used with SLOW response (1 second time constant), as stated by the OSHA regulation 1910.95-Occupational Noise Exposure. The ambient noise is of primary interest due to the fact that there is no particular sound of interest other than a composite of sounds from many sources near and far. To avoid any significant effect of extreme temperatures on the instruments. The temperature of both the SLM and the Dosimeter had to approach the work area's ambient temperature before each use.

At specific points located at appropriate far-field or quasi-free field distances from the source machines within every section, the highest noise levels were recorded. The SLM was rotated around its vertical axis until a maximum reading was reached (Berger, 1986) and then was oriented at an angle of 70° to 80° to the sound source (Harris, 1991). Then the reading was recorded on a Noise Survey Data Form (see Figure 2), which was designed for this survey.

4.4 Hearing Protection Devices (HPD) Use

In order to determine the number of employees wearing hearing protection devices while working on the pump floor, walk-through tours were made along a fixed route and repeated at random times. This route was walked in opposite directions, so that the end point might randomly become the starting point for the next tour. The observations were conducted by using work sampling techniques. The number of workers found to be wearing hearing protection out of the total numbered observed was recorded for each tour. Random observations of employees wearing hearing protection on the pump floor yielded data to show that approximately 35% of the employees actually wear hearing protection devices on a regular basis. In other words, the percent of people wearing hearing protection devices while working on the pump floor is very low even when they have been provided with one type of earmuff and two types of earplugs.

CHAPTER 5

RESULTS

5.1 Individual Noise Levels

A total of 15 readings were recorded for each area of the #2 unit and 7 readings for the #1 unit. Noise levels for the #1 unit range from 78.5 dBA to 119.3 dBA and 86.6 dBA to 108.8 dBA in the #2 unit. Only 7 readings were taken from the #1 unit due to the fact that this unit does not operate as often as the #2 does (it is very expensive to run the #1). Readings were taken daily from 09/14/92 to 11/20/92, during the afternoon from 12:30 p.m. to 3:30 p.m. when the demand for electricity is higher and the machinery is working at its maximum capacity. It would not be accurate to use a single SLM reading to estimate the daily Equivalent Noise Level because of the fluctuating nature of many industrial noise levels. As a result, a minimum of 10 readings are required to determine an average sound pressure level within 90% confidence limits with a confidence interval of ± 1.3 dB (Harris, 1991).

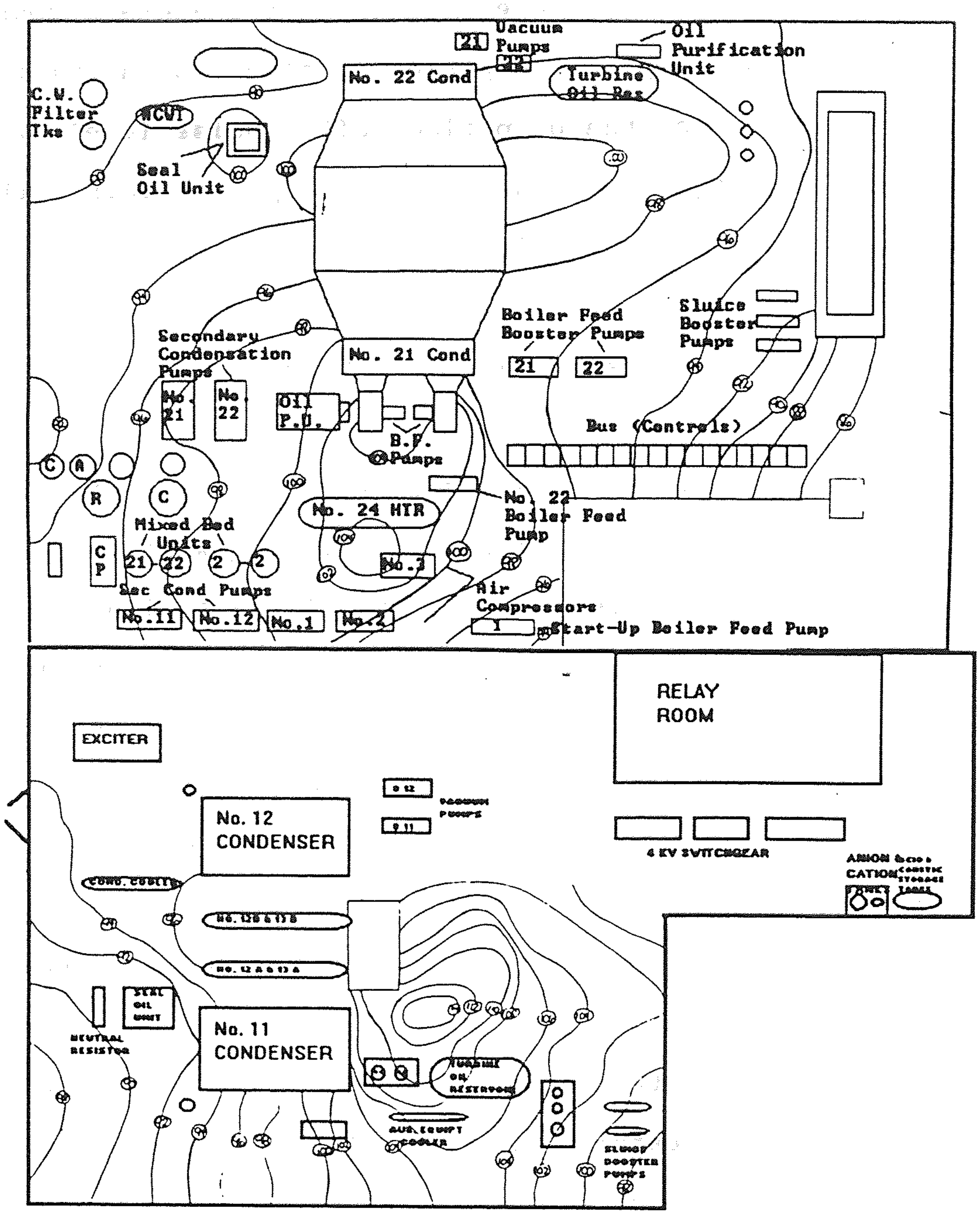
5.2 Calculation of Equivalent Noise Level (L_{eq})

A preliminary noise survey was conducted to find general noise exposure levels around work sites. Therefore, it was determined that a detailed noise survey should be conducted in all work sites of the pump floor. Those areas with the highest noise levels could be identified after the noise survey is completed. The detailed noise survey data are presented in Appendix A. The Equivalent Noise Level, which is the average sound level during a specified period of time, is calculated for each area of the pump floor after noise levels were taken. The **Equivalent Noise Level (L_{eq})** for each work site is estimated by using the following formula:

$$L_{eq} = 10 \log \left(1/N \ \Sigma \ 10^{Li/10} \right)$$

The equivalent sound levels for the 261 sections of both the #1 and the #2 units are also shown in Appendix A. All the equivalent levels calculated fell above 87 dBA for the #2 unit and 85 dBA for the #1 (except for two readings), which indicates that all areas on the pump floor are high noise level areas. Also, it indicates that hearing protection devices such as earmuffs and earplugs are required while working on the pump floor. The area around the #1 unit showed the highest reading, 116 dBA; this is the area behind No. 11 condenser. For the #2 unit, a reading of 105.2 dBA was found around Heater number 24. This is due to the fact that the most noisy equipment, number 1, number 2 and number 3 compressors, the secondary condensate pumps, and number 21 and number 22 B.F. Pumps surround this area. The number 1 unit area highest equivalent noise level was 116 dBA and the minimum lowest noise level was facing 21

Figure 3 Sound Level Contours for #1 and #2 Units



80 dBA. For number 2 unit, the highest and lowest equivalent noise levels are 105 dBA and 89 dBA, respectively.

5.3 Sound Level Contours

After the noise levels were measured, sound level contours were used to illustrate to workers and management the degree of exposure at different areas of the pump floor. Using this tool, the dominant noise sources can be identified. The measurement positions shown in Figure 3 were selected on approximately 20 square feet grid patterns. The contours lines are based on 2-dBA changes in the measured sound level.

5.4 Use of Personal Hearing Protection

As could be seen on the Noise Survey Data Form on Appendix A, the unit with the highest readings was the #1 unit with noise levels above 116 dBA. Under this high noise condition, any noise abatement scheme should be applied (OSHA, 1992), preferably engineering controls. However, personal protection, as a bottom line protection, should at least be considered. If the employee wears single hearing protection with a Noise Reduction Rate (NRR) of 27 dBA, for example, he or she would be exposed to 106 dBA noise level. This means that the employee is not allowed to work at that area more than .87 hour (OSHA, 1992). Therefore, other measures (i.e., engineering controls) or double protection is warranted. Even when it was found that these extremely high noise levels were due to a vapor leak on one of the pipes for the #1 unit, double hearing protection is mandatory until the leak is fixed. In the case of double hearing protection, which is the maximum protection, the attenuation achievable would be 18 dB allowing the employee work for a maximum of 2.6 hours.

The highest noise level around the #2 unit was 105 dBA which yields 87 dBA after double hearing protection attenuation is used and 95 dBA (muffs) or 92 (plugs) with single-hearing protection. This means that even when a person is allowed to work 12.1 hours, (at 87 dBA) the action level of 85 dBA was reached.

5.5 Noise Doses and Time Weighted Average (TWAs)

In order to determine the worker's noise exposure, a noise dosimeter is used. This is the most practical way to measure noise exposure of a worker during a work-shift under the circumstances where the worker may move around between several locations in the course of his or her duties, or perform a variety of operations during the day. The dosimeter was mostly worn by those employees who work on a frequent basis in areas such as #22 Forced Draft Fan, and #3 Air Compressor on the pump floor (from 6/29/92 to 11/18/92).

As mentioned before, the dosimeter was calibrated before every use. After calibration, the microphone is attached to the shoulder of the employee under study and the dosimeter's body is placed on to the operator's belt or in his/her pocket. For the purpose of this study, the popular "A" weighing is used. The data collection started regularly at 7:30 a.m. and extended to 11:30 a.m. and then from 12:30 p.m. to 3:30 p.m. from 06/29/92 to 12/10/92. The dosimeter was turned off during lunch break because off-the-job noise was not considered. Many employees go out during lunch breaks and are exposed to non-job related noises. Note that the power plant does not provide an in-house cafeteria.

At the end of each day the dosimeter was plugged into the computer, the data was downloaded; and information regarding employee's name, date, location, and comments was saved. The Dosimeter's printout can include a heading, a data summary, event data, 1 to 3 histograms, and 1 or 2 percent time statistical distributions. A typical data summary includes the calibration level, the start and end time, the peak, maximum and minimum level, the peak maximum and minimum time, the time constant, the 8 hour dose, weighing factors and the noise average level, TWA, and so on. The histogram showing the employees' exposure to noise throughout the work-shift is computed as the data is accumulated with the appropriate exchange rate and excluding data less than the threshold, which is 50 dBA (see Appendix B). When a noise level is less than 50 dBA, the reading is not stored and the output on the histogram is 0 dBA. Each minute an integrated average level is computed and stored. The statistical distribution shows the accumulated dose at each level. It is accumulated without a threshold, so it exclude any dose accumulated below the threshold. From Table 2, the highest TWA was 102 with a dose of 550.01%.

Table 2 Dosimeter Data for 22 Forced Draft Fan

TWAs	FREQ	DOSE	LAVG	PEAK
93	1	147.24	95.5	140.6
94	1	181.79	95.6	145.5
95	1	189.95	97.6	140.6
96	3	233.00	97.5	135.8
97	4	282.83	99.1	144.4
98	3	310.99	100.5	144.8
99	3	348.17	103.8	130.9
100	1	400.00	100.00	130.0
101	1	460.00	103.50	141.0
102	1	550.01	104.6	143.3

The dosimeter output shows that TWAs range from 93-dBA to 102-dBA. Of the total of 20 employees studied in the 22 Forced Draft Fan area, 100% of the TWAs were higher than 90-dBA and 100% were higher than 85-dBA.

The noise level with higher frequency is 97 dBA with a total of 4 observations. It is followed by 96.98 and 99, each with a frequency of 3. This confirms that at least the use of single hearing protection is recommended around this area.

As shown on Table 3, #3 Air Compressor area revealed that the highest noise reading is 96 dBA and the lowest 87 dBA. The noise levels with higher frequencies are 90, 91 and 92 dBA; 70% of the readings fell above the OSHA PEL of 90 dBA and 100% are above the action level.

Table 3 Dosimeter Data for #3 Air Compressor

TWA	FREQ	DOSE	LAVG	PEAK
87	1	61.97	88.7	129.0
88	2	75.00	89.1	130.2
89	2	87.21	91.3	142.6
90	3	108.13	92.4	145.5
91	3	115.48	92.8	144.8
92	3	120.90	94.2	142.1
93	2	147.24	95.5	140.6
94	2	181.79	95.6	145.5
95	1	190.30	97.6	140.6
96	1	233.00	97.5	135.8

Table 4 Single and Double Hearing Protection Attenuation

TWA	ADJUSTED TWA AFTER SINGLE HEARING ATTENUATION (MUFF NRR=27)	ADJUSTED TWA AFTER DOUBLE HEARING ATTENUATION (MUFF NRR=27 & PLUG NRR=33)	ADJUSTED TWA AFTER SINGLE HEARING ATTENUATION (PLUG NRR=33)
87	77	69	74
88	78	70	75
89	79	71	76
90	80	72	77
91	81	73	78
92	82	74	79
93	83	75	80
94	84	76	81
95	85	77	82
96	86	78	83
97	87	79	84
98	88	80	85
99	89	81	86
100	90	82	87
101	91	83	88
102	92	84	89

5.6 In Field Noise Levels with Single and Double Hearing Protection Calculation

The single hearing attenuation is calculated by subtracting 7 from the Noise Reduction Rate (NRR), dividing the remainder by 2 (or multiply by 50%) and then subtracting the remainder from the A-weighted TWA (OSHA Technical Manual, 1990). To calculate double hearing attenuation, the following equations are used:

Approximate Field Attenuation is (NRR - 7)/2 = Z

$$Z + 5 = Y$$

$$TWA - Y = \text{Adjusted TWA for}$$

double hearing protection. The adjusted TWAs for the 40 employees are shown on Table 4. In this case,the earplug and earmuff NRRs are 33 and 27, respectively. The approximate Field Attenuation of earplugs and earmuffs when both are worn are 18 and 15 respectively. Certainly, the hearing device with the greater NRR provides better protection. Even when using earmuffs, the noise levels range from 77 to 92 dBA which means that noise does not pose any threat to employees wearing single hearing protection, except for two of the readings. The last three employees were exposed to decibels higher than 90 which means that double hearing protection would be necessary. Finding this will be proven after the real mean range is determined.

Figure 4 Hearing Protection Devices Questionnaire

Instructions: Please circle the letter that best answer the question.

1) What type of HPD do you wear?

   a) earplugs   b) earmuffs   c) both   d) none

2) Why do you prefer it?

   a) cleanliness   b) comfort   c) NRR
   d) other reason: ______________________________

   (noise reduction rate: the greater the NRR is the better is the protection)

3) Where required, how often do you wear HPD?

   a) 100% of the time   b) 75-99%   c) 50-74%
   d) never

4) Why don't you wear HPDs (if your answer was no to question #1?

   a) uncleanliness   b) discomfort
   c) other reason: ______________________________

5) How can the company improve Hearing Protection usage?

   ____

After the noise survey is done and the most hazardous areas are identified, the next step is to consider various noise control measures such as: alterations in engineering design, limiting the time of exposure, or using personal protective equipment to achieve the desire level of exposure. Personal hearing protection should be worn when engineering or administrative methods cannot be implemented to control the noise source.

5.7 Questionnaire

In order to determine an employee's attitude towards Hearing Protection Devices before the Behavior Modification Techniques are implemented, a questionnaire shown on Figure 4 was developed and handed out to a total of 30 people from the station. The results of the questionnaire on Table 5 show that approximately 35% of the station's population wears hearing protection devices while the remaining 65% do not. Included in the 35% are those who wear them on a daily basis and those who do frequently.

Table 5 Questionnaire Results (in percentages)

EARPLUGS	EARMUFFS	BOTH	NONE
10	20	5	75
EARPLUGS			
CLEANLINESS	COMFORT	NRR	OTHER
15	80	4	1
100%	**75-99%**	**50-74%**	**NEVER**
47	33	15	5
UNCLEANLINESS	DISCOMFORT	OTHER	
85	15	0	
EARMUFFS			
CLEANLINESS	COMFORT	NRR	OTHER
85	10	5	0
UNCLEANLINESS	COMFORT	OTHER	
22	75	3	

CHAPTER 6

STATISTICAL ANALYSIS

6.1 BACKGROUND

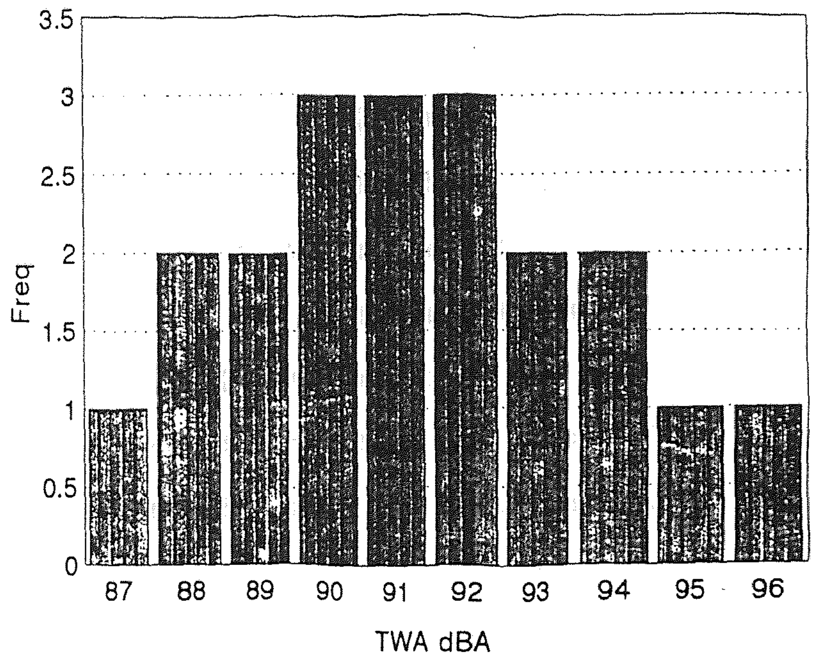
The OSHA Hearing Conservation Amendment (HCA) is based on exposures for individuals, requiring that every person whose TWA equals or exceeds the action level of 85 dBA on any single day be placed in the HCP. The next step is to determine whether any employee's TWA ever exceeded the 85 dBA action level, the 90 dBA PEL or what the range of the 95% confidence interval around the mean TWA for workers might be in a particular job classification or place. This last goal is realized by the application of standard statistical techniques.

Occupational noise regulations require that whenever employees are exposed to excessive noise level (i.e., 90 dBA TWA or higher), feasible administrative or engineering controls should be used to reduce these levels. When these control measures cannot be completely accomplished, and/or while such controls are being initiated, personnel should be protected from the effects of excessive noise levels. Such protection can, in most cases, be provided by wearing suitable hearing protective devices as a bottom-line protection (Plog, 1990).

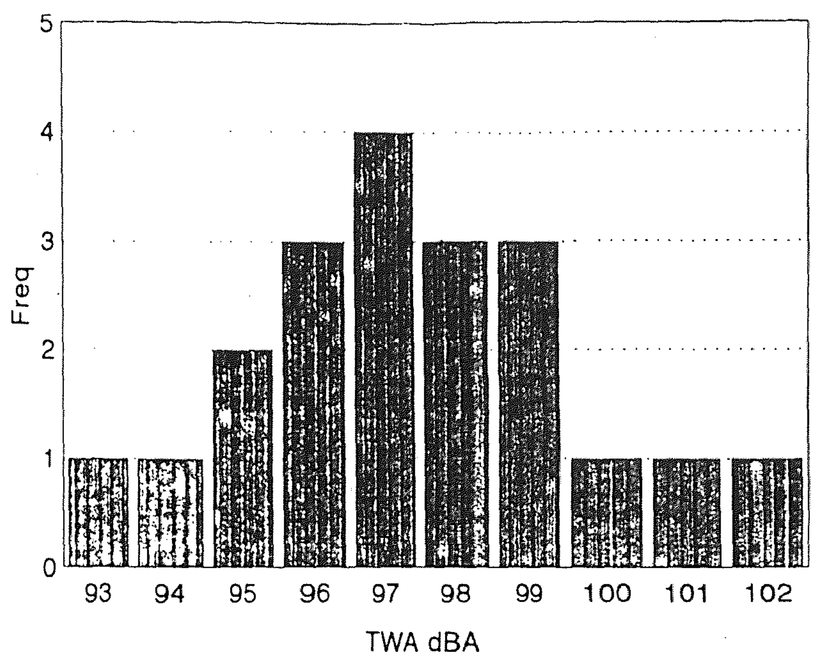
Statistical analysis of the sound survey data can help the surveyor describe employee noise exposures with more confidence than by looking at raw dosimeter measurements. In this particular case, we attempt to find the range of the 95% confidence interval around the mean TWA for employees working more frequently in certain areas of the pump floor and/or from a particular job classifications. From all data gathered, the maintenance group classification was mostly at risk at two different areas of the pump floor. These two areas are known as the #22 Forced Draft Fan and the #3 Air Compressor. Even when the same job classification was the mostly affected, two different statistical analyses had to be conducted because of the noise fluctuations between the two areas.

Even when greater number of observations allows the confidence interval around the mean exposure to be defined more narrowly and reduces the influence of any outside influences, it does increase the cost of the study. Thus, a sample size from the whole population should be selected. According to the size of the population (N=37), the minimum sample size needed to ensure at the 95% confidence level that the sampling will include one or more observations for employees in the top 10% of the distribution is 20 (Leidel, Busch, and Lynch, 1977). Therefore, for the 37 employees in each group, a total of 20 measurements were required.

Figure 5 Histograms



Frequency Histogram for the Sample Data
22 Forced Draft Fan



Frequency Histogram for the Sample Data
3 Air Compressor

The sound survey around the #22 Forced Draft Fans area yielded levels from 93 dBA to 102 dBA. After determining the frequency of each of the TWA values, a histogram was drawn to determine the shape of the distribution, which in this case displays an approximation of the normal distributions function of bell-shaped curve (see Figure 5).

The mean (mu) of the sample's TWA values, which is an indicator of the center of the data, yielded 97.3 dBA for the #22 Forced Draft Fan area and the standard deviation (S) equals 2.32 dBA. For the #3 air compressor area, mu=91.2 dBA and S=3 dBA.

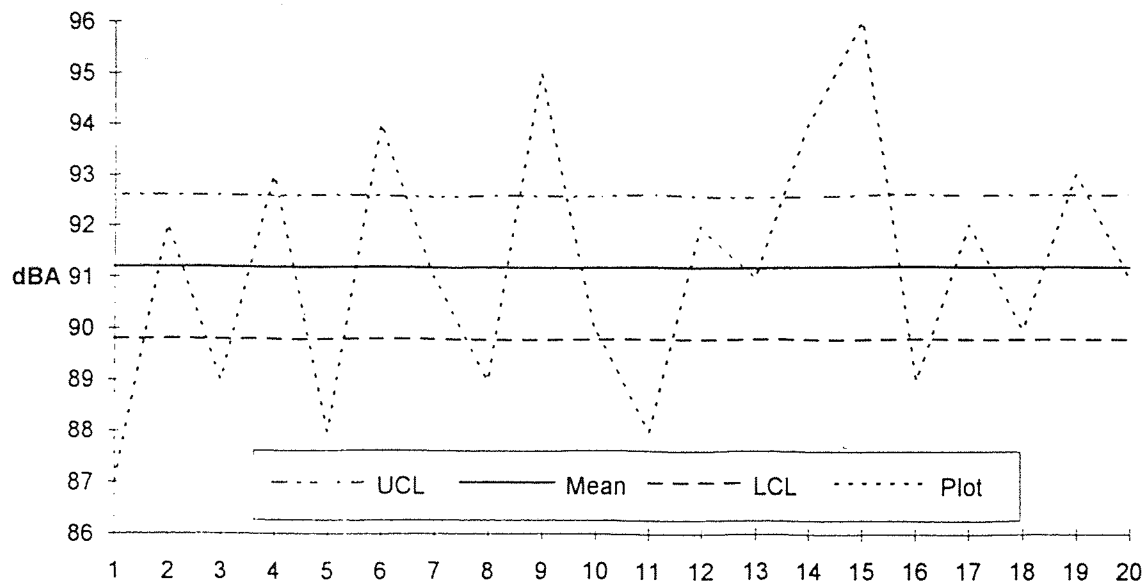
After the mean and standard deviation are calculated the next step is to check the normality of the sample distribution by applying the Chi-Square Goodness-of-Fit statistic. The range of values is divided into classes, each of which must have an expected frequency of at least 5 observations.

$$\text{Chi-square} = \Sigma(\text{observed} - \text{expected})^2/\text{expected}$$
$$= 1 \text{ with } 1 \text{ degree of freedom}$$

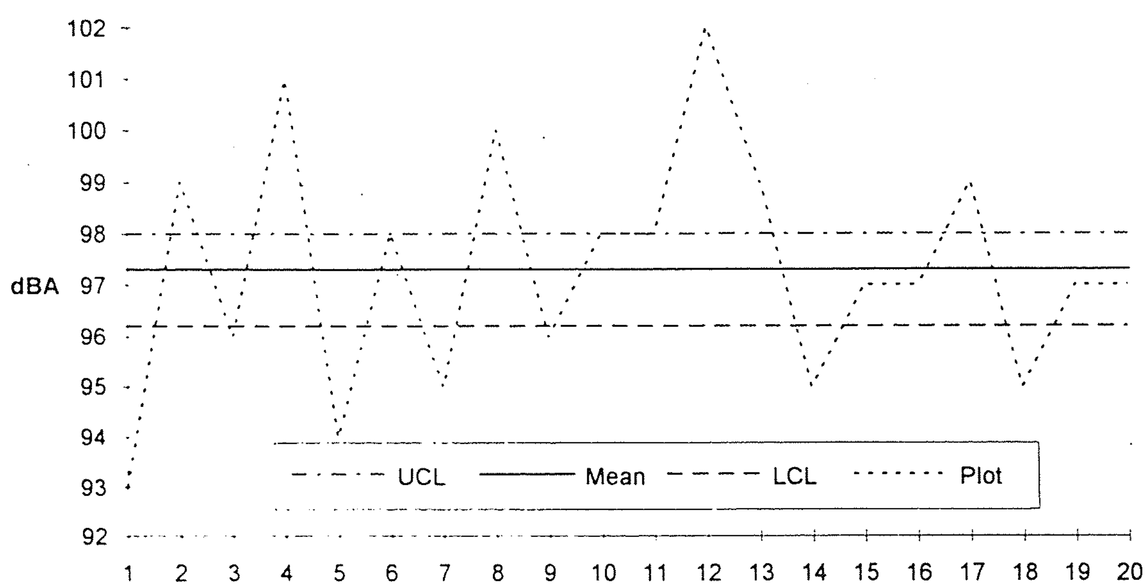
for the #22 Forced Draft Fan area and 1/5 for #3 air compressor area. After determining the critical value of the Chi-Square (3.84), it can be concluded that the distribution may be considered normal at the 95% confidence level because the critical value is greater

Figure 6 Upper and Lower Control Charts for 22 Forced Draft Fan and #3 Air Compressor

 # 3 Air Compressor



22 Forced Draft Fan



than the calculated value, which is 1 for the #22 Forced Draft Fan area and 1/5 for the #3 air compressor area.

The 95% confidence interval around the mean is a way of estimating the true population mean. For a Two-Sided Confidence Interval mean with $t_{.975}$ and 19 degrees of freedom, the upper/lower control limits (UCL & LCL) are:

$$\begin{aligned} UCL &= \text{mean} + t_{.975}(S/n^{.5}) \\ &= 98 \end{aligned}$$

$$\begin{aligned} LCL &= \text{mean} - t_{.975}(S/n^{.5}) \\ &= 96.2 \end{aligned}$$

Therefore, the true mean of the TWA values for the population sample falls within the range of 96.2 to 98 with 95% confidence. Likewise, the UCL and LCL for the #3 air compressor area are 92.6 dBA and 89 dBA, respectively. The Control Charts, which show if the individual's exposure noise TWAs fell above or below the Upper/Lower Control Limits are shown in Figure 6. According to the chart, 11 out of 20 readings fell beyond the control limits for #3 Air Compressor area and 12 out of 20 in the 22 Forced Draft Fan area.

The one-sided upper confidence interval (UCL_1) for the mean is most important for the purpose of this study because it determines how high a value the mean might take. This provides a more conservative test which may be appropriate for compliance related decisions. The UCL_1 is:

$$UCL_1 = \text{mean} + t_{0.95}(S/n^{.5})$$
$$= 98.19$$

This means, with a 95% confidence that the true population mean is less than a TWA of 98.2 dBA in the #22 Forced Draft Fan area and 92.38 for the #3 Air Compressor area. Therefore, theoretically if a worker is wearing hearing protection with 10 dB or more noise reduction capability, he or she is in compliance with OSHA when working in that specific area.

CHAPTER 7

RECOMMENDATIONS

Unsafe behaviors that could lead to accidents and/or injuries can be eliminated or at least minimized by implementing a behavior modification program (i.e., incentive program) in the workplace. Management as well as other employees should be part of the whole program in order for it to be a successful one. A possible incentive program that could be implemented is explained in the following paragraphs.

Walk-through tours around the pump floor are done to observe the number of employees wearing hearing protection out of the total number observed over a period of 2 weeks. These observations, as well as subsequent ones, would be conducted using work sampling techniques. The tours will be made following the same route at randomly chosen sampling times.

After the baseline observations are made, a safety meeting including both experimental and control groups will be held to discuss:

1) the hazards of working in noisy environments
2) the OSHA noise standard and the hearing protection equipment required
3) a description of the hearing mechanism, how hearing loss could be avoided
4) the effects of noise in stress and high blood pressure, and

5) Noise Control Survey results (mean and range values at the pump floor) by using demonstrations, discussion and hand-outs. Workers in the experimental group will receive additional information regarding the study.

Audiometric tests, beginning on the next day after the lecture, will be given to the employees from the selected department. These employees will be selected randomly. The tests will take place one at the beginning of the work-shift and the second at the end of the shift, and the respective audiograms will be shown and explained to workers immediately after completing the second test. Notable differences (if any) between the two tests will be explained. The workers will keep one copy of the audiogram and the second copy will be hung on a bulletin board. Each worker should be tested twice, one not wearing any HPD and the second wearing HPD in order to observe the effect of noise on temporary hearing loss during the day.

After receiving their audiograms, the employees will be encouraged to make a commitment to wear HPDs. Signing pledge cards could help them enforce the habit of wearing HPDs. The duration of the pledge card commitment will be one month. After signing the pledge cards, one copy will be given back to the signer and another copy will be hung on the bulletin board for the same period of the commitment.

Several safety items (safety boots, safety equipment for home and car, fire extinguishers, dinner certificates, jackets, company stock, vacation day, etc.) would be "purchased" according to the number of times an employee is seen wearing hearing protection.

Another area to be explored in the future is spectral analysis of noise sources on the pump floor. It is known that frequencies above 500 Hz have a greater potential for causing hearing loss than noise at lower frequencies. In order to determine the frequency spectrum component of the noise at the pump floor, the use of an Octave Band Analyzer or Fast Fourier Transform is recommended.

CHAPTER 8

CONCLUSIONS

After evaluating the data provided by both the Sound Level Meter and the dosimeter, an effective hearing conservation program becomes mandatory if any employee's exposure exceeds 85 dBA for 8 hours. It is mandatory that the use of hearing protection devices (HPDs) be supplied in order to protect workers from being exposed to hazardous noise levels. Also, HPDs should be utilized carefully so that employee's noise exposure should be less than OSHA's 85 dBA action level. It has been proven that double hearing protection provides better protection than single hearing protection, and that this approach should be used in those cases where noise levels are higher than 98 dBA with an exposure time of eight hours.

The employee's TWAs could have been underestimated due to random factors such as worker mobility and/or job task changes. Non-random sources that could have affected the TWAs are, for instance, calibration errors, technical errors in measurement procedures, and systematic changes in exposure level. According to the OSHA's single and double hearing protection attenuation equation, the attenuation for each of the devices yielded 10 dB and 18 dB, respectively.

No relationship between the season of the year and the noise levels recorded during this time could be demonstrated. According to the current data, there was no substantial difference between the noise readings taken in August and those taken in November. However, noise levels could vary slightly as a function of temperature during the season of the year. According to the company's annual report, the past summer was very cool and sales for electricity decreased while consumption gas increased. On the other hand, a slight difference between the noise levels between the morning and the afternoon was found which demonstrates that when the demand for electricity increases, the machinery generates more noise. As a result, the noise levels recorded in this survey could have been under-estimated.

As mentioned before, working on the pump floor is not done on a daily basis; it is required only when maintenance or a special job is called for. Currently, there are not many people who have suffered Standard Threshold Shifts (STS). The company's industrial hygiene records show that only three cases have occurred over the last two years. However, those employees who have had Standard Threshold Shifts could have been exposed to potential hearing loss even when they were wearing hearing protection devices. According to recent company studies, the percentage of people who do not wear hearing protection is high. By using work sampling techniques, it was found that only 35% of the working population at the power generating plant wear hearing protection devices. Thus, even for those who do actually wear hearing protection, the hazard of hearing loss still exists.

Although it may involve costly engineering controls, the use of sprayed-on cellulose fiber-based material applied to the walls and ceiling of the room to reduce reverberation effects (the treatment reduces 5 dBA while improving thermal insulation) may be feasible. Preventive maintenance and enclosing are two other the possible solutions to alleviate the noise exposure. While preventive maintenance could forestall possible high noise levels generated when there is friction between gears and other involving parts, enclosing may be feasible at least for those machines that generate the highest noise levels, such as air compressors and forced draft fans. Another highly recommended method is the placement of high-efficiency baffles around the most noisy equipment.

Another control that could be used in order to minimize employees' noise exposure is administrative control. Employees most at risk can be rotated to other jobs where noise exposure is minimal. Work schedules of less than eight hours minimize the exposure time at noisy areas.

Scientific research has been conducted to determine the percent of actual hearing protection usage provided in the field. More scientific investigation needs to be made to observe worker's behavior with respect to hearing protection usage. Certain statistical techniques, such as work sampling, are required to measure accurately how employees protect themselves from hazardous noise levels.

8.1 Future Experiment

Better behavior modification techniques need to be developed and applied. They are a very efficient tool to improve hearing protection usage among employees. A few studies have indicated that when incentives programs are implemented, employees' compliance improves. Random observations of employees' hearing protection are required in order to estimate with a certain percent of confidence that the observations are accurate. Also, employees' awareness of noise hazards (i.e., from lectures, audiometric testing, etc.) is a must. Finally, employees complying with the behavior modification program should be rewarded with items that are both really attractive and related to safety, as well.

APPENDIX A: NOISE LEVEL READINGS AND EQUIVALENT NOISE LEVELS OF UNITS 1 & 2

NOISE SURVEY #1 UNIT

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
		09/24	10/30	11/16	11/17	11/18	11/19	11/20									
A01		84.5	90.4	91.8	91.1	90.5	89.2	88.2									90
A02	CO-2 Vaporizer	81.1	91.7	93.6	92.5	90.8	90	89.7									91
A03	Turbine Area - West Cntrl Cntr	80.0	93.8	97.0	96.6	93.3	92.4	90.3									94
A04	Boiler Drain Tank	78.5	96.9	100.9	100.0	96.7	96.1	93.2									97
A05	Panel # 207	81.8	100.4	105.0	104.5	101.0	99.8	97.4									101
A06	Telephone Cabinet	83.5	104.1	108.9	107.0	103.5	102.9	100.0									104
A07		84.9	106.1	109.9	109.1	105.4	104.9	101.8									106
A08	HTG.Steam Water Heater	86.9	103.2	108.1	106.5	102.2	101.9	98.8									104
A09	Flood Pump Motor	91.0	100.0	104.3	102.9	99.7	99.1	96.8									101
A10	Fire Protection Manifold	95.3	97.8	99.1	100.0	96.6	96.4	94.3									98
B01	Gen Bus Cooling Unit	83.1	90.1	114.1	90.9	90.0	88.8	88.3									89
B02		81.6	92.5	113.6	92.2	91.6	90.7	90.7									92
B03	N0.11 HTR. Drain Pump	81.3	91.1	108.8	93.0	92.7	90.7	91.2									92
B04	Boiler Drain tank	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
B05	No. 11 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
B06	LP HTR & S-Up Drn.Va.Cntrl	80.7	105.6	114.1	110.4	107.4	108.1	103.6									109
B07	Low Pres. Hter 14A & 15A	83.0	110.6	113.6	112.9	111.1	109.6	105.3									111
B08	Turbine Oil Reservoir	89.9	105.4	108.8	108.6	105.1	104.5	101.8									106
B09	Turbine Oil Transfer Pumps	92.7	102.7	106.0	105.3	102.1	101.5	99.5									103
B10	Sluice Booster Pumps	92.4	101.2	104.1	103.9	101.1	100.4	98.0									101
C01	Bus Cooling Unit	83.2	90.7	91.9	91.6	90.4	92.1	89.6									91
C02	Neutral Resistor	84.7	91.5	92.4	91.9	91.4	90.9	90.7									91
C03	Seal Oil Unit	80.4	92.4	93.5	93.5	93.9	92.8	92.3									93
C04	No. 11 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C05	No. 11 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C06	No. 11 Condenser	111.1	112.7	113.5	113.8	110.5	109.7	106.6									112
C07		80.1	115.2	117.0	119.3	116.3	115.9	112.2									116
C08	Turbine Oil Cooler	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
C09		90.7	103.5	107.1	106.7	103.7	102.8	101.1									104
C10	Weld and Strees Rel. Cabinet	97.2	102.0	104.2	103.9	101.8	101.5	99.7									102
D01	C.T. & P.T. Term Cabinet	89.1	94.8	94.7	94.8	93.7	94.4	94.3									94
D02	Gas Dryer And H−2 Panel	88.6	95.8	95.2	95.8	95.3	94.3	95.8									95
D03		90.6	97.1	95.6	95.6	95.6	94.5	97.0									96
D04	No. 12A Low Pressure Heater	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D05	No. 12A Low Pressure Heater	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D06		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D07		80.4	99.0	117.0	103.9	100.2	100.3	105.7									109
D08	Hyd. Cplg. Coolers	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D09	Hyd. Cplg. Oil Pumps	92.9	103.3	104.7	105.2	103.2	102.9	100.6									103
D10	Cont. Air Dryers & Filters	93.3	99.9	103.1	102.7	101.1	101.1	98.7									101
E01	Telephone	91.1	94.4	94.6	94.6	93.8	93.7	94.0									94
E02	Condensate Cooler	92.2	95.0	95.2	94.9	94.5	94.1	95.0									95
E03	Condensate Cooler	93.0	95.7	95.4	95.1	95.2	94.5	95.4									95
E04	No. 12B Low Pressure Heater	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E05	No. 12B Low Pressure Heater	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E06		88.9	96.4	102.3	102.1	98.8	98.4	96.2									99
E07		89.4	97.2	99.1	105.4	102.4	101.1	99.6									101
E08		85.6	96.4	98.3	105.0	102.5	102.5	99.8									101
E09		89.6	99.3	101.2	102.1	99.7	100.1	98.0									100
E10	BF Pmp Lube Oil Cler & Ctrl	88.3	97.3	99.5	98.8	97.1	97.3	96.0									97
G10		96.0	91.2	97.5	97.6	95.8	95.9	95.2									96
G11		93.7	86.9	94.8	94.9	92.4	92.1	91.7									93
G12		89.4	86.9	91.9	91.2	88.6	88.8	88.2									90
G13		83.5	84.0	87.1	87.6	84.9	85.2	84.1									85
G14		81.6	80.9	83.8	84.2	81.8	82.4	81.2									82
G15		80.9	78.5	81.5	80.5	79.0	81.3	79.8									80

NOISE SURVEY #2 UNIT

1992

		9/14	9/16	9/18	9/21	9/23	9/24	9/25	10/7	10/13	10/15	10/19	10/20	10/30	11/4	11/6	
GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
C01	Shop Doors	90.9	91.3	95.6	92.3	92.6	95.9	95.7	94.4	93.7	94.0	94.0	94.4	97.3	93.4	94.1	94
C02	Silica Analyzer	90.2	91.2	97.5	92.3	92.4	97.3	96.9	95.1	94.5	94.9	95.4	96.5	97.6	94.6	95.1	95
C03	West Side 21 mB	88.9	92.1	99.9	92.7	95.1	100.1	99.3	97.9	96.9	98.3	96.7	98.0	98.5	97.9	98.2	98
C04	West Side 22 & 23 mB	92.0	95.5	104.0	94.8	95.5	103.5	103.5	101.0	101.8	101.3	100.7	101.0	100.5	101.7	100.8	101
C05	West Side 24 mB	90.0	96.9	98.5	97.2	96.8	103.1	101.7	100.4	100.5	99.5	98.8	99.3	99.8	100.3	99.0	100
C06	Elec. Cont. Gas	90.8	93.8	100.0	98.2	95.6	99.5	98.3	97.6	•94.8	94.6	93.7	94.5	97.5	95.2	94.6	97
C07	Air Comp #1 & #2 Panel	86.6	97.3	97.4	97.7	98.4	99.4	99.6	99.0	•93.7	91.8	92.3	93.6	97.5	94.8	93.4	97
C08	Start Up Bler Fd Pump #1	86.6	95.9	96.8	96.4	96.9	97.7	98.0	97.5	•91.3	94.8	91.9	92.4	95.9	93.8	91.8	96
C09	Exit Resin Sluice Pump	87.3	94.8	97.2	96.5	97.4	96.9	97.3	96.6	•93.3	93.5	92.9	94.4	95.0	93.0	93.2	95
C10		88.1	93.4	94.5	93.1	93.6	93.9	94.7	94.2	•89.6	91.0	90.6	90.5	95.5	93.8	92.0	93
C11	No. 1 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C12	No. 1 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C13	No. 1 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
C14	No. 1 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D01	F.W. Rack	91.1	91.6	96.2	92.8	92.6	96.4	95.7	94.5	93.4	94.3	94.2	94.6	96.2	95.7	94.8	95
D02	Mixed Bed Control Panel	91.3	93.4	98.7	94.0	94.2	97.5	97.7	95.9	94.9	95.2	95.1	95.4	97.1	96.7	95.8	96
D03	Mixed Bed Unit No. 21	92.7	95.1	100.8	96.3	96.2	100.0	99.9	98.6	98.1	97.4	97.9	97.4	97.9	98.1	98.4	98
D04	Mixd Bed Uts No 22 & 23	93.5	96.7	103.7	98.4	98.4	103.7	102.6	101.5	100.1	99.9	99.9	100.1	99.4	100.6	99.8	101
D05	Mixed Bed Unit No. 24	96.7	99.0	101.7	100.3	101.7	104.4	103.7	102.8	•99.4	99.3	99.1	100.2	99.5	100.3	99.8	101
D06	HTR North Side 24	95.1	103.4	111.6	108.8	107.2	106.9	106.9	107.0	•98.4	98.0	97.8	98.0	98.5	99.8	98.8	105
D07	No. 3 Compressor	92.0	105.0	107.0	106.6	104.3	106.1	106.2	106.2	•95.1	94.7	95.3	95.5	96.4	96.3	95.5	102
D08	No. 3 Compressor	91.4	96.8	101.4	100.9	100.7	101.5	102.2	102.1	•94.7	94.6	95.9	95.9	94.9	95.1	95.4	99
D09	Resin Regen. Pumps	93.2	96.2	98.2	97.9	97.8	98.6	99.0	98.5	•93.0	93.9	94.6	94.8	95.3	95.9	93.6	97
D10	Stairway	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D11	No. 2 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D12	No. 2 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
D13	No. 2 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
D14	No. 2 Relay Room	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E01	Ammonia Pump	91.2	91.3	94.0	93.1	93.2	94.6	94.8	92.9	92.6	94.0	94.8	94.3	94.4	94.4	93.4	**94**
E02	Resin Storage Tank	93.7	94.0	96.2	94.8	94.7	95.7	96.4	95.1	95.0	95.6	96.5	96.5	95.9	96.0	96.1	**96**
E03	Cation Regen Tank	96.0	96.5	98.6	97.7	97.4	97.9	98.9	97.6	97.9	98.1	98.1	98.1	97.3	97.5	97.1	**98**
E04		96.6	97.7	99.8	98.2	97.9	99.9	100.0	98.1	97.5	98.0	98.8	99.0	98.1	98.5	97.7	**98**
E05	Turb Area West Ctrl Cbnet	97.3	99.0	101.2	100.1	99.8	100.3	101.2	100.1	99.9	98.7	99.9	100.2	98.5	99.1	99.3	**100**
E06	No.21 BF pmp.Thttle Vlv	99.8	100.3	101.8	101.7	102.5	103.1	103.9	102.5	102.4	103.2	104.5	102.1	100.5	102.7	103.0	**102**
E07	No. 24 Heater	99.9	101.0	102.7	101.3	102.6	102.7	103.0	103.1	102.0	102.1	104.1	103.3	102.1	102.0	101.4	**102**
E08	No.22 Bler Fd Pump Cont	95.8	99.0	100.0	100.7	100.3	100.8	101.3	101.3	101.0	99.3	100.2	99.7	99.6	101.0	99.4	**100**
E09	No.22 BF PMP Thttle Vlve	95.4	98.5	101.0	101.3	100.9	100.6	100.9	100.4	99.2	99.2	99.3	99.3	100.6	101.0	100.6	**100**
E10		96.4	97.1	99.3	99.5	99.7	99.2	100.4	96.8	96.6	96.3	96.6	96.6	96.0	96.8	96.3	**98**
E11	No. 21 Group Bus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E12	Valve Control Center	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E13	Volt 220 Dist. Cabinet	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
E14	Volt 440 Dist. Cabinet	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
F01	East Res Cln Anion Tank	90.8	91.1	93.4	92.2	92.7	91.6	93.6	94.3	91.8	92.3	93.8	92.3	91.7	93.0	91.7	**92**
F02	East Res Cln Cation Tank	94.1	93.6	96.1	95.1	94.9	94.5	96.2	97.3	94.4	95.1	97.0	95.0	95.2	95.3	95.0	**95**
F03	Anion Regen Tank #2	97.5	96.7	98.4	98.1	97.9	97.3	98.9	98.0	97.6	97.8	98.1	98.3	97.5	97.8	97.9	**98**
F04	Sec. Cond. Pump #22	101.0	99.7	101.5	100.4	103.6	100.0	101.9	101.3	101.2	101.6	101.8	101.4	100.0	101.1	100.8	**101**
F05	Oil Purification Unit	97.7	99.6	100.0	99.4	100.6	99.6	101.4	100.0	99.8	100.2	101.6	103.6	99.7	100.3	100.0	**100**
F06	No.21 Bler Fd Pump	108.2	101.6	103.0	100.4	105.0	106.6	105.3	103.9	103.5	103.1	103.9	107.3	103.9	105.6	104.9	**104**
F07	No.21 Bler Fd Pump	101.8	102.3	104.6	105.1	105.7	104.3	105.4	104.8	103.8	103.4	104.9	105.2	105.5	104.4	104.5	**104**
F08	No.22 Main Bler Fd Pump	96.8	97.9	101.5	101.4	102.4	100.4	102.4	102.3	101.8	102.5	103.2	101.7	102.3	103.5	102.4	**101**
F09	Trench and Floor Drain	95.0	96.5	98.9	99.3	99.3	97.9	99.2	99.0	98.7	99.6	99.6	98.8	97.3	97.9	98.0	**98**
F10		96.2	96.5	98.4	98.8	98.4	97.0	98.2	95.0	94.1	94.1	94.4	95.7	93.8	94.7	94.6	**96**
F11	No.21 Bler Fd Bster Pump	90.3	92.5	95.2	94.7	93.1	91.8	94.6	91.6	90.8	91.0	93.5	91.1	90.6	91.9	91.5	**92**
F12	No.22 Bler Fd Bster Pump	88.0	89.9	91.4	91.5	90.1	89.2	90.4	88.9	88.7	89.1	90.2	89.6	88.6	89.1	88.9	**90**
F13		86.7	88.3	89.5	89.0	88.2	89.0	89.2	87.2	87.0	87.9	88.9	89.3	88.5	88.4	89.1	**88**
F14	Soot Blower Panel	86.6	86.4	87.4	86.0	85.6	85.9	87.7	85.6	86.1	87.6	87.0	87.6	86.9	87.0	87.9	**87**
G01	Phase Bus # 3	90.8	91.3	91.4	91.7	92.0	93.0	93.7	91.9	92.5	93.1	93.2	92.7	91.9	92.4	92.4	**92**

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
G02	Floor Drain	92.4	91.8	93.6	94.1	92.8	93.7	94.2	92.7	92.9	93.0	93.5	93.4	93.1	92.5	92.8	93
G03	Exciter Cubical	95.5	94.8	95.0	95.2	94.9	95.7	95.5	94.4	94.9	94.9	96.4	95.9	94.3	95.4	93.6	95
G04	Floor Drain	95.2	96.3	96.3	96.1	96.8	97.2	97.1	96.4	96.8	96.7	97.5	97.6	96.1	96.1	95.8	97
G05	Turning Gear Trans Switch	95.6	96.0	97.0	96.6	96.5	97.6	97.6	96.9	96.1	96.8	96.0	97.1	96.1	96.2	95.3	97
G06	No. 21 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G07	No. 21 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G08	No. 21 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G09	No. 21 Condenser	94.5	93.8	94.9	95.7	95.7	95.0	96.0	95.3	94.3	94.8	95.7	94.5	95.2	94.6	93.5	95
G10	Gland Steam Condenser	96.0	95.6	96.5	96.4	96.4	96.3	96.5	96.5	95.9	96.0	96.6	96.5	95.9	96.2	95.7	96
G11	No 22 Boiler FeedB. Pump	96.4	94.2	93.7	94.2	93.5	94.4	94.8	93.8	93.9	94.6	96.3	94.7	93.5	94.8	94.0	94
G12	Cold RH 1st & 2nd Hot RH	94.3	93.6	92.5	94.0	94.0	93.9	95.7	92.0	91.6	94.6	94.2	93.3	92.6	93.2	93.1	93
G13	Serv. Water Cooler Ctrols	93.2	92.0	91.7	93.3	92.0	92.9	93.2	90.7	91.9	93.9	93.5	92.2	91.4	93.2	92.9	92
G14	Sluice Booster Pumps	93.1	88.3	88.0	91.0	88.8	89.0	91.3	86.9	95.8	87.6	88.1	90.0	87.8	88.8	88.4	90
H01	Under Main Bus Leads	91.6	89.5	90.1	91.3	91.5	90.6	92.6	90.7	90.9	91.7	92	92.2	90.9	91.3	91.2	91
H02	Main Bus Ccooler	90.6	89.6	90.4	91.6	91.0	90.8	92.3	90.7	90.8	91.1	90.6	91.2	90.1	90.2	90.8	90
H03		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H04		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H05	H–2 Gas Dryer	95.0	94.2	94.6	94.5	94.3	94.2	95.5	94.4	95.2	94.6	95.3	95.2	94.5	94.3	94.4	94
H06	No.22 LP Feedwater Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H07	No.22 LP Feedwater Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H08	No.22 LP Feedwater Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H09	No.22 LP Feedwater Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H11	Gland Leak Off Flow	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
H12		93.5	94.9	92.6	95.1	94.1	94.3	95.3	92.7	92.6	94.6	96.4	94.3	94.1	94.6	95.2	94
H13	Cold R.H. 2nd	95.1	94.7	93.6	94.9	93.3	93.7	96.2	92.4	93.8	95.0	95.3	93.3	92.8	93.8	94.3	94
H14	Sluice Booster Pumps	93.4	92.8	91.5	93.6	91.7	91.9	93.5	91.3	91.1	92.9	93.5	91.6	92.5	92.1	93.1	92
I01	Phase Bus 3	89.6	87.6	88.2	89.8	89.6	89.1	90.6	88.3	88.7	89.7	89.4	89.7	89.0	90.1	89.0	89
I02	Phase Bus 3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I03	Phase Bus 3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I04	H–2 Panel	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
I05	Seal Unit	93.6	93.1	94.0	93.9	94.4	94.2	94.4	92.9	92.9	93.9	93.7	94.4	93.9	94.1	93.9	93
I06	No.23 LP Feed Water Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I07	No.23 LP Feed Water Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I08	No.23 LP Feed Water Hter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I09		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I10		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I11		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
I12		97.6	97.9	94.7	96.6	97.1	98.7	97.2	97.3	97.0	98.3	98.4	96.1	96.4	98.4	98.7	97
I13	R.H. Desup. Water Panel	93.3	95.0	94.3	96.0	95.4	95.5	96.8	94.1	95.2	96.1	97.0	94.5	93.8	94.6	94.2	95
I14	No. 21 Cont. Air Dryer	93.7	92.7	91.6	96.3	93.3	93.1	94.2	91.7	92.7	94.0	93.7	92.9	91.0	93.5	94.0	93
J01	Reclaimed Water Pump	87.0	88.2	89.6	89.3	89.1	88.0	89.8	88.3	88.3	89.9	87.6	90.3	88.7	90.8	89.4	89
J02	City Water Filter Tanks	89.0	88.9	89.7	88.4	90.1	89.0	91.3	88.5	90.6	90.4	90.1	90.8	89.3	89.6	90.2	90
J03	Aux. Water Cooling Contls	90.4	90.9	92.4	91.6	92.0	91.2	92.9	89.9	89.7	90.1	90.0	90.3	90.5	90.8	90.5	91
J04	Trench & Fl Drain H2 Oil	93.6	91.9	93.7	92.1	92.6	91.6	93.2	92.0	90.9	91.8	92.3	92.6	90.8	91.4	92.0	92
J05	Seal Oil Unit	92.5	92.0	92.2	90.7	91.9	91.2	92.9	89.3	89.8	90.2	90.7	90.7	90.1	90.3	90.2	91
J06	No. 22 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
J07	No. 22 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
J08	No. 22 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
J09	No. 22 Condenser	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
J10	Gland Leak Off	99.6	95.5	98.4	98.6	101.0	101.7	99.5	99.1	99.9	99.9	100.0	99.3	99.4	99.7	98.4	100
J11	Turbine Oil Reservoir	98.9	104.4	97.2	97.5	100.1	98.8	99.1	97.0	97.7	98.2	98.1	97.6	97.4	97.5	97.4	99
J12	Hot R.H. 2nd & 1st C.R.H.	95.3	96.1	96.6	97.4	97.2	96.6	98.7	94.8	95.7	97.1	98.4	97.5	97.4	95.5	97.3	97
J13	Floor Drain	92.8	98.0	99.4	99.2	97.2	97.6	99.5	98.1	97.0	99.6	101.9	100.1	95.2	94.6	95.3	98
J14	Dust System Air Dryer	91.0	92.0	92.7	99.7	92.9	92.5	94.5	91.2	92.1	93.1	94.0	92.6	91.9	93.1	92.9	93
K01		88.1	88.4	88.9	88.7	88.7	88.2	89.9	86.1	89.6	86.5	87.5	87.2	86.3	91.0	90.0	89
K02	Floor Drain	89.4	89.7	91.3	90.6	90.4	90.6	91.6	88.2	88.9.0	88.0	89.2	87.6	87.4	88.6	89.0	90
K03	Hatch	89.7	90.1	91.6	90.6	91.1	90.7	91.8	87.8	88.2	88.4	89.3	89.1	88.7	88.7	88.2	90
K04	No. 21 Drain Cooler	91.6	91.1	91.6	91.1	91.0	91.4	92.1	89.1	87.7	90.1	90.6	90.0	90.5	90.1	89.9	90
K05		90.7	90.3	91.2	90.9	90.7	90.2	91.5	89.7	85.8	90.2	90.5	90.1	90.3	90.6	90.3	90
K06	No.22 Prim Cond Pump	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

GRID	LOCATION	dB1	dB2	dB3	dB4	dB5	dB6	dB7	dB8	dB9	dB10	dB11	dB12	dB13	dB14	dB15	Leq
K07	HTR Drain Pumps	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
K08		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
K09		96.5	97.8	96.9	96.6	96.4	96.2	97.8	96.2	97.2	97.1	97.1	96.8	96.6	96.6	96.0	**97**
K10	No.21 & No.22 Vac Pump	95.8	97.3	97.6	98.3	98.5	97.9	98.8	97.9	99.1	99.2	98.5	98.0	97.7	98	97.9	**98**
K11	Waste Water Tank	96.3	97.1	96.7	96.9	97.0	96.8	98.0	96.4	97.0	97.7	97.3	97.2	96.5	96.9	96.5	**97**
K12	Oil Purification Unit	94.2	95.6	96.1	96.6	95.3	96.1	97.3	94.7	94.0	95.5	95.1	96.2	94.9	94.9	94.9	**96**
K13		93.5	94.7	94.7	98.4	95.3	94.5	97.2	93.7	93.0	94.9	95.7	95.4	94.2	94.3	95.1	**95**
K14	Phone	91.8	89.6	91.1	95.1	89.0	89.3	97.2	88.3	87.8	89.7	90.0	89.7	91.9	94.3	92.6	**92**
L01	Doors	91.5	90.1	90.9	89.8	89.2	88.3	90.8	87.1	86.6	87.1	87.7	87.2	86.3	87.8	87.8	**89**
L02		89.6	90.6	92.7	91.2	90.1	90.7	93.1	87.6	86.9	89.2	87.5	87.8	87.4	88.2	88.0	**90**
L03	No. 21 Intake Fan	90.7	90.5	91.1	91.1	90.3	90.3	91.7	88.9	87.8	87.9	89.0	88.3	88.5	88.7	88.3	**90**
L04	No. 22 Intake Fan	91.2	91.1	91.1	91.0	92.6	90.6	92.1	89.5	89.3	90.0	90.5	89.7	90.2	89.4	89.1	**90**
L05	No. 22 Prim Cond Pump	90.2	90.8	91.4	90.5	91.2	91.2	91.9	90.6	90.7	91.0	91.6	91.2	91.0	91.3	90.3	**91**
L06	Pumps	90.7	89.8	89.9	90.7	90.7	90.0	90.3	92.0	90.8	91.8	91.8	91.3	91.4	91.5	91.4	**91**
L07		91.4	90.3	89.9	91.0	91.1	90.2	90.9	91.7	91.6	91.4	91.6	91.2	92.4	91.2	91.1	**91**
L08		94.5	91.0	91.2	91.9	91.5	93.9	93.3	93.5	91.9	92.4	94.0	92.9	93.0	92.1	91.2	**92**
L09	Light. Panel & No.21 V.P.	94.1	93.3	94.0	94.4	94.6	94.0	94.9	94.6	94.2	94.6	93.7	94.0	93.1	94.2	94.9	**94**
L10	No.23 Int Fan & No.22 V.P.	94.5	94.4	94.2	94.9	94.6	94.4	95.5	93.9	94.4	95.4	94.4	95.3	94.2	95.2	94.0	**94**
L11	No. 24 Intake Fan	95.6	94.8	95.1	94.8	95.1	95.5	96.2	94.1	94.9	95.4	94.3	95.4	93.9	94.6	94.8	**95**
L12	No. 25 Intake Fan	94.1	94.2	93.9	94.5	94.7	94.5	95.6	93.7	93.5	94.2	93.8	95.2	93.5	94.6	93.7	**94**

APPENDIX B: EXAMPLE OF A DOSIMETER OUTPUT

Use arrow keys to select or hit ENTER to continue.

M-27 DATA SUMMARY

CAL LEVEL---110.1dB	UNIT------ 1		
START TIME-- 8h:07m	END TIME--- 8h:22m	RUN TIME- 6h:40m:51s	PAUSE-65h:34m:43s
PEAK LEVEL--145.5dB	MAX LEVEL--113.6dB	MIN LEVEL--- 51.00dB	UPPER LIM.--115dB
PEAK TIME---11h:10m	MAX TIME---10h:53m	MIN TIME-----12h:37m	U.L.-- 0h: 0m: 0s
EXCHANGE RATE- 5 dB	90 dB THRESHOLD	80 dB THRESHOLD	3dB EXCHANGE RATE
CRITERION---- 90 dB	LAVG------- 95.6dB	LAVG--------- 95.7dB	LEQ------- 96.9dB
RANGE-------- 50 dB	TWA-------- 94.3dB	TWA---------- 94.4dB	SEL-------140.7dB
TIME CONSTANT--slow	DOSE-------181.79%	DOSE---------183.41%	DOSE------412.00%
WEIGHTING---------A	8HR DOSE---217.69%	8HR DOSE-----219.62%	8HR DOSE--493.34%
HOUR DOSE			

```
                                  Hit any key to continue.
 1 MIN HISTOGRAM DATA
 90 dB THRESHOLD, 5 dB EXCHANGE RATE

        50         70         90         110        130        150
TIME     +----+----+----+----+----+----+----+----+----+----+
 8:07:00  0 dB
 8:08:00 +---------+----- 80.75 dB
 8:09:00  0 dB
 8:10:00  0 dB
 8:11:00 +---------+---------+- 93.13 dB
 8:12:00 +---------+---------+---- 98.01 dB
 8:13:00 +---------+---------+---- 98.38 dB
 8:14:00 +---------+---------+--- 97.63 dB
 8:15:00 +---------+---------+---- 98.76 dB
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